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MILITARY STANDARD

INTEROPERABILITY AND PERFORMANCE STANDARDS FOR FIBER OPTIC COMMUNICATIONS SYSTEMS

AMSC N/A AREA SLHC

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FOREWORD

1. This military standard is approved and mandatory for use by all Departments and Agencies of the Department of Defense (DoD) in accordance with DoD Directive 4640.11, dated 21 December 1987

2. Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: Commander, U.S. Army Information Systems Engineering Command, ATTN: ASB-SET-T, Fort Huachuca, Arizona 85613-5300 by using the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document, or by letter.

3. Originally, Military Standard 188 (MIL-STD-188) covered technical standards for tactical and long-haul communications, but later evolved through revisions (MIL-STD-188A, MIL-STD-188B) into a document applicable to tactical communications only (MIL-STD-188C).

4. The Defense Communications Agency (DCA) published DCA Circulars (DCACS) promulgating standards and engineering criteria applicable to the long-haul Defense Communications System (DCS) and to the technical support of the National Military Command System (NMCS).

5. As a result of a Joint Chiefs of Staff (JCS) action, standards for all military communications are now being published in a MIL-STD-188 series of documents. The MIL-STD-188 series is subdivided into a MIL-STD-188-100 series covering common standards for tactical and long-haul communications, a MIL-STD-188-200 series covering standards for tactical communications only, and a MIL-STD-188-300 series covering standards for long-haul communications only. Emphasis is being placed on developing common standards for tactical and long-haul communications published in the MIL-STD-188-100 series.

6. This document contains technical standards and design objectives (DOs) for long-haul and tactical digital fiber optic communications systems. The terms "system standard" and "design objective (DO)" are defined in FED-STD-1037. In this document, the word "shall" identifies mandatory system standards. The word "should" identifies DOs which are desirable but not mandatory.

ACKNOWLEDGMENT

The material in appendix C is reproduced with permission from American National Standard for Telecommunications--Digital Hierarchy--Optical Interface Specifications: Single-mode, ANSI Tl.106-1988, copyright 1988 by the American National Standards Institute.

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APPENDIXES

1. SCOPE

1.1 Scope. This document provides mandatory standards and optional design objectives (DOs) necessary to ensure system interoperability. This document also establishes a level of performance for long-haul and tactical fiber optic links necessary to satisfy the requirements of a majority of users. This document is not intended to serve as a stand-alone, comprehensive reference for the design of new equipment and facilities or the preparation of specifications. Consequently, hardware specific design details are not contained herein. These and other design details must be based on specific requirements and must be carefully tailored in accordance with the provisions of DoD Directive 5000.43.

1.2 Applicability. This document applies to the design and development of new digital fiber optic equipment, assemblies, and subsystems used in long-haul and tactical communications systems. This standard is not mandatory for systems used in the following applications:

a. On-board mobile platforms such as ships, aircraft, and tanks.

b. Test ranges.

c. Radar and instrumentation remoting.

d. Local area networks (LANs).

It is not intended that existing fiber optic facilities be immediately converted to comply with this standard. New facilities and those undergoing major modification or rehabilitation shall comply with the standards contained herein. It is also not intended that these standards inhibit advances in communications technology. Such advances are encouraged by including DOs which should be achieved or exceeded if economically feasible, and by standardizing design parameter values rather than the technology used to achieve them. If deviation from this standard is required, see the waiver procedures contained in DoD Directive 4640.11

2. APPLICABLE DOCUMENTS

2.1 Government documents.

2.1.1 Specifications, standards, and handbooks. Unless otherwise specified, the following specifications, standards, and handbooks of the issue listed in that issue of the Department of Defense Index of Specifications and Standards (DODISS) specified in the solicitation form a part of this standard to the extent specified herein (see 6.2).

STANDARDS

FEDERAL

FED-STD-1037	Glossary of Telecommunication Terms

MILITARY

MIL-STD-188-114	Electrical Characteristics of Digital Interface Circuits
MIL-STD-188-115	Interoperability and Performance Standards for Communications Timing and Synchronization Subsystems
MIL-STD-1678	Fiber Optics Test Methods and Instrumentation

(Copies of the referenced Federal and military standards are available from the Department of Defense Single Stock Point: Commanding Officer, Naval Publications and Forms Center, ATTN: NPFC 106, 5801 Tabor Avenue, Philadelphia, PA 19120-5099. For specific acquisition functions, these documents should be obtained from the contracting activity or as directed by the contracting officer.)

2.1.2 Other Government documents, drawings, and publications. The following other Government document forms a part of this standard to the extent specified herein. Unless otherwise specified, the issue is that cited in the solicitation.

DEPARTMENT OF DEFENSE (DoD)

DoD Directive (DoDD) 5000.43	Acquisition Streamlining

(Application for copies should be addressed to the Commanding Officer, Naval Publications and Forms Center, ATTN: NPFC 106, 5801 Tabor Avenue, Philadelphia PA, 19120-5099.)

2.2 Non-Government publications. The following documents form a part of this standard to the extent specified herein.Unless otherwise specified, the issues of the documents which are DoD adopted are those listed in the issue of the DODISS cited in the solicitation. Unless otherwise specified, the issues of the documents not listed in the DODISS are issues of the documents cited in the solicitation (see 6.2).

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

ANSI Standard T1.102-1987	Digital Hierarchy--Electrical Interfaces Specifications: Single-mode.

(Application for copies should be addressed to the American National Standards Institute (ANSI), 1430 Broadway, New York, NY 10018-3308.)

TELECOMMUNICATIONS INDUSTRIES ASSOCIATION (TIA)
(formerly Electronic Industries Association (EIA))

EIA-455 Series Standards	Standard Test Procedures for Fiber Optic Fibers, Cables, Transducers, and Connecting and Terminating Devices

(Requests for copies should be addressedto the Telecommunications Industries Association (TIA), 2001 Eye Street, NW, Washington, D.C. 20006. ATTN: Standard Sales Office (Telephone (202) 457-4966).)

2.3 Order of precedence. In the event of conflict between the text of this document and the references cited herein, the text of this standard shall take precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

3. DEFINITIONS

3.1 Terms. Definitions of terms used in this document shall be as specified-in the current edition of FED-STD-1037. In addition, the following definitions are applicable for the purposes of this standard.

Cable cutoff wavelength. For a single-mode fiber under specified length, bend, and deployment conditions, the wavelength at which the fiber's second order mode is attenuated a measurable amount when compared to a multimode reference fiber.

Optical interface. Within a fiber optic communications link, any point at which an optical signal is passed from one equipment or medium to another without transduction to an electrical signal.

Optical line code. Sequences of optical pulses suitably structured by waveform or other characteristics to permit information transfer over the optical link.

Optical receiver dynamic range. The ratio in decibels (dB) between the minimum receiver input optical power required for a specified bit error ratio (BER) and the receiver input power at which overload occurs.

Peak wavelength. The wavelength at which the intensity of the source is maximum.

> NOTE: In some cases, it is appropriate to specify the "central wavelength" (of an optical source) in place of the "peak wavelength". See 6.3 for further explanation of these terms.

Zero-dispersion slope. The value of the dispersion slope at the fiber's zero-dispersion wavelength. (See next term.)

Zero-dispersion wavelength. A wavelength at which the fiber dispersion coefficient is zero. In single-mode fibers, it occurs where the dispersion has been designed such that the dispersion coefficient goes to zero.

3.2 Abbreviations and acronyms. Abbreviations and acronyms used in this document are defined below. Those listed in the current edition of FED-STD-1037 have been included for the convenience of the reader.

ANSI	American National Standards Institute
BCI	bit-count integrity
BER	bit error ratio
dB	decibel(s)
DCA	Defense Communications Agency
DCE	data circuit-terminating equipment
DepSO	Departmental Standardization Office
DO	design objective
DoD	Department of Defense
DoDD	Department of Defense Directive
DODISS	Department of Defense index of Specifications and Standards
DTE	data terminal equipment
DUI	data unit interval
EIA	Electronic Industries Association
FOTP	fiber optic test procedure
FSC	Federal Supply Class
FSG	Federal Supply Group
JCS	Joint Chiefs of Staff
kbps	kilobits per second
km	kilometers)
LAN	local area network
LED	ight emitting diode
Mbps	megabits per second
MLM	multilongitudinal-mode (laser)
nm	nanometer(s)
NMCA	National Military Command System
OASD	Office of the Assistant Secretary of Defense
OC	optical carrier
OFSTP	optical fiber system test procedure
PCM	pulse-code modulation
P&L	Procurement and Logistics
PPM	parts per million
Ps	picosecond(s)
SDM	Standardization and Data Management
SLM	single longitudinal-mode (laser)
SMF	single-mode fiber
TIA	Telecommunications Industries Association
TDM	time-division multiplexing
um	micrometers)
us	microseconds)
WDM	wavelength-division multiplexing

4. GENERAL REQUIREMENTS

4.1 General Description of a digital fiber optic link. A fiber optic link includes, as a minimum, an optical transmitter, an optical receiver, and an optical fiber waveguide which is normally enclosed within a cable. The link may also include repeaters, connectors, and splices. Normally, the transmitter accepts an electrical input signal and delivers an optical output signal, and the receiver accepts an optical input signal and delivers an electrical output signal. The fiber serves as the medium for propagating optical signals between the transmitter and the receiver. A representative digital fiber optic link is shown on figure 1. Note that this figure shows only one direction of transmission. A full-duplex link would have both a transmitter and a receiver at each end. Transmitters and receivers may incorporate additional functions such as multiplexing and demultiplexing. The electrical and optical interfaces may be built into the data terminal equipment (DTE) or data circuit-terminating equipment (DCE). Elements of the optical transmitter and the optical receiver (including optical sources and optical detectors) may be included in a single piece of equipment. In some applications, the fiber optic elements may be built into the DTE or DCE.

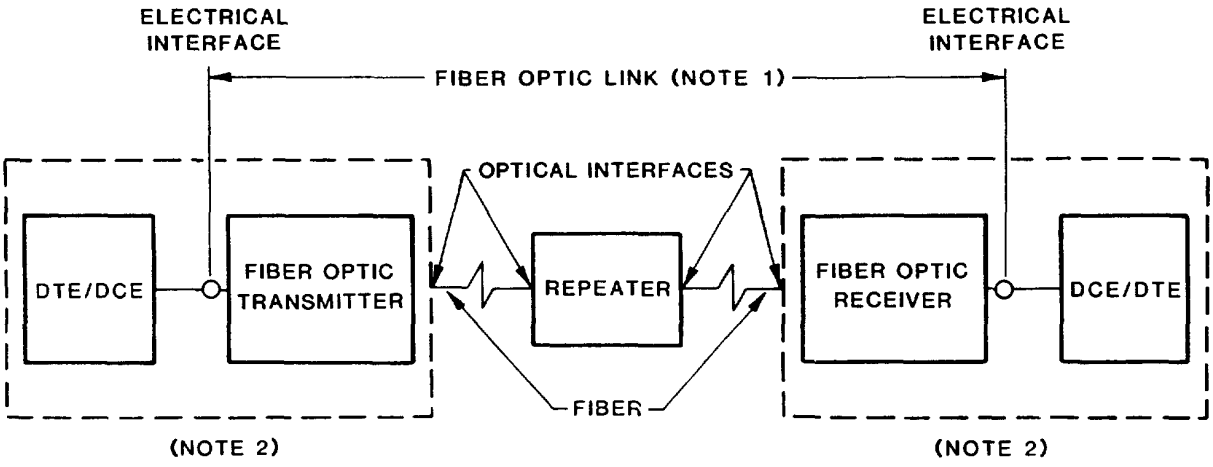
NOTE: The term "repeater" refers to a device that amplifies, reshapes, retimes, and retransmits digital signals, or performs any combination of these functions. If all of the functions are performed, the device is referred to as a "regenerative" repeater.

4.2 Electrical interface characteristics.

4.2.1 MIL-STD-188-114 requirement. Except as stated in 4.2.2, digital fiber optic links shall provide the capability for a digital interface characteristic for binary signals at the link input and output terminals, either balanced or unbalanced, as appropriate, in accordance with the applicable requirements of MIL-STD-188-114.

NOTE 1: The requirement to provide a MIL-STD-188-114 interface capability means that a fiber optic link shall either have terminals with MIL-STD-188-114 interface characteristics, or be designed with the necessary provisions (such as replacement modules or plug-in printed circuit cards) to implement a MIL-STD-188-114 interface when needed. In accordance with the tailoring requirements of DoDD 5000.43, the procurement activity must make the necessary decisions regarding the interface capabilities of a fiber optic link and the engineering solutions needed to implement those capabilities.

NOTE 2: In those cases where a fiber optic link must interoperate with a DCE or DTE that has a nonstandard digital interface, it is expected that a MIL-STD-188-114 interface will be provided at the DCE or DTE. This can be accomplished by (a) replacing the nonstandard DCE or DTE with equipment that meets MIL-STD-188-114 requirements, (b) modifying the nonstandard equipment, or (c) adding an interface box that performs the necessary conversion between the nonstandard characteristics of the DCE or DTE and the MIL-STD-188-114 interface of the fiber optic link.



NOTES:

1. The link may include connectors, splices, and repeaters.
2. The DTE/DCE and the fiber optic transmitter or receiver may be combined into a single unit.

FIGURE 1. Digital fiber optic link (one direction only).

NOTE 3: In some cases, it is not feasible to modify or replace nonstandard DCE or DTE. For example, the DCE or DTE might be the property of a commercial carrier, or replacement or modification might be uneconomical due to the large quantity of the equipment involved. In such cases, it is acceptable to equip the fiber optic link with the nonstandard interface characteristic needed to connect and interoperate with the DCE or DTE. This nonstandard interface characteristic of the fiber optic link shall be in addition to its capability to provide an interface characteristic per MIL-STD-188-114.

NOTE 4: The reason for requiring a fiber optic link to provide the capability for a MIL-STD-188-114 interface, even if not immediately needed, is to facilitate the replacement of nonstandard DCE or DTE with standard equipment at a later date. Without this capability, the replacement of old nonstandard equipment would require either new nonstandard equipment or an upgrading of the fiber optic link to accommodate standard equipment. The additional cost of the MIL-STD-188-114 interface capability for new fiber optic links, even if the capability is not immediately needed, is considered acceptable since it will greatly facilitate the introduction of future generations of standard equipment and reduce the proliferation of nonstandard equipment.

4.2.2 Other types of electrical interfaces Not standardized. North American commercial equipment operating at the DS1, DSIC, DS2, DS3, and DS4NA data signaling rates shall be exempt from the mandatory MIL-STD-188-114 interface requirement. The following European rates shall also be exempt: 8.448 Mbps, 34.368 Mbps, 139.264 Mbps, and DSLE (2.048 Mbps).

NOTE: The North American data signaling rates are as follows:

DS1 = 1.544 Mbps;
DSIC = 3.154 Mbps;
DS2 = 6.312 Mbps;
DS3 = 44.736 Mbps; and
DS4NA = 139.264 Mbps.

4.3 Protection of signal sense. A fiber optic link shall not invert the logic and signal sense of binary signals transmitted from the input to the output of the fiber optic link

4.4 Optical line code. The line code shall not restrict the number of sequential binary ""Ones"" or "zeros" that may be contained in the information to be transmitted over a fiber optic link.

4.5 Clocking. Where clocking is required (i.e., for synchronous systems),cTocking equipment and method of clock recovery shall conform to the requirements of MIL-STD-188-115.

4.6 Wavelength-division multiplexing. Under consideration.

4.7 Test and measurement procedures. DoD-adopted procedures for measuring characteristics of fiber optic components are contained in MIL-STD-1678, and shall be used whenever appropriate.

NOTE: DoD procedures are often adopted versions of Electronic Industries Association (EIA) procedures (with or without modification). Consequently, many DoD and EIA procedures are similar or identical. EIA test procedures for fiber optic components are referred to as fiber optic test procedures (FOTPS) and are contained in the EIA-455 series of standards. EIA test procedures for fiber optic systems are referred to as optical fiber system test procedures (OFSTPs) and will be published in appropriate EIA standards.

5. DETAILED REQUIREMENTS

5.1 Input data signaling rates.

5.1.1 Long-haul. Fiber optic systems used in long-haul applications shall be capable of accepting input data signaling rates of up to at least 44.736 Mbps. This rate is the DS3 rate described in American National Standards Institute (ANSI) Standard Tl.102-1987.

5.1.2 Tactical. As a minimum, tactical fiber optic links shall have the capability of accepting the following input data signaling rates:

72 kbps	1024 kbps
128 kpbs	1152 kpbs
144 kpbs	1536 kpbs
256 kpbs	2048 kpbs
288 kpbs	2304 kpbs
512 kpbs	4096 kbps
576 kpbs	4608 kbps

NOTE: These rates are multiples of 8000 bps. Specifically, they correspond to 8000N, where N takes on the following values:

9, 16, 18, 32, 36, 64, 72, 128, 144, 192, 256, 288, 512, and 576.

5.2 Optical line rates. Not standardized.

NOTE: Appendix C lists a set of optical line rates (for single-mode systems) adopted by ANSI. While these rates are not a mandatory part of MIL-STD-188-111A, the designers of long-haul systems should be aware of their existence. Use of such rates within DoD will facilitate interfaces with commercial links using the same rates. While MIL-STD-188-111A does not require that these rates be used within DoD, it does not preclude or discourage their use.

5.3 Service-channel bit stream.

5.3.1 Long-haul. A service channel shall be provided for fiber optic links used in long-haul applications. This service channel may be routed in-band (i.e., through fiber optic cable), or out-of-band (i.e., through another medium, such as radio or metallic cable). The capacity (bit rate) of this service channel is not standardized.

5.3.2 Tactical. Tactical fiber optic links shall have the capability of accepting service channel bit streams at the following rates: 16 kbps and 32 kbps.

5.4 Link availability.

5.4.1 Long-haul. Availability of the active elements within an unrepeatered long-haul link shall be 0.999984. Unavailability of a link shall be defined by the following conditions:

a. Link degradation results in a bit error ratio (BER) that exceeds 10^{-4}.
b. The degradation occurs for a period in excess of 60 consecutive seconds (one minute).

For example, a link experiencing a BER in excess of 10^{-4} for two minutes is unavailable for one minute.

NOTE: This BER value equates to 8.4 minutes of downtime per year. It applies to all active elements within each unrepeatered link. For links with n repeaters, the availability shall be:

$$\text{Availability} = 1-0.000016(n+1)$$

5.4.2 Tactical. Not standardized.

5.5 Bit error ratio.

5.5.1 Long-haul. The bit error ratio (BER) for a long-haul fiber optic link shall not exceed (K) x 10^{-11}, where K is the length of the link in kilometers.

5.5.2 Tactical. The BER of a tactical fiber optic link shall not exceed 10^{-9}.

5.6 Mean time to loss of bit-count integrity. Under consideration.

5.7 Jitter.

5.7.1 Jitter requirements for long-haul systems. Jitter at the 1.544-Mbps and 44.736-Mbps interfaces of fiber optic systems carrying PCM/TDM signals shall meet the requirements given in the subparagraphs below. Jitter is not standardized for other system rates, except that it must be within limits that can be applied to DTE and DCE without causing an increase in BER or loss of bit-count integrity (BCI).

5.7.1.1 Tolerable input jitter. Long-haul fiber optic links shall be capable of tolerating input jitter (at the electrical interface shown on figure 1) up to the levels shown on figures 2 and 3. These levels are expressed in terms of peak-to-peak sinusoidal jitter amplitude versus jitter frequency. Tolerable input jitter is defined as the jitter which can be applied to the link without causing an increase in BER or loss of BCI.

5.7.1.2 Intrinsic jitter. Intrinsic jitter is defined as the output jitter of a fiber optic link in the absence of input jitter. Intrinsic jitter limits are under consideration.

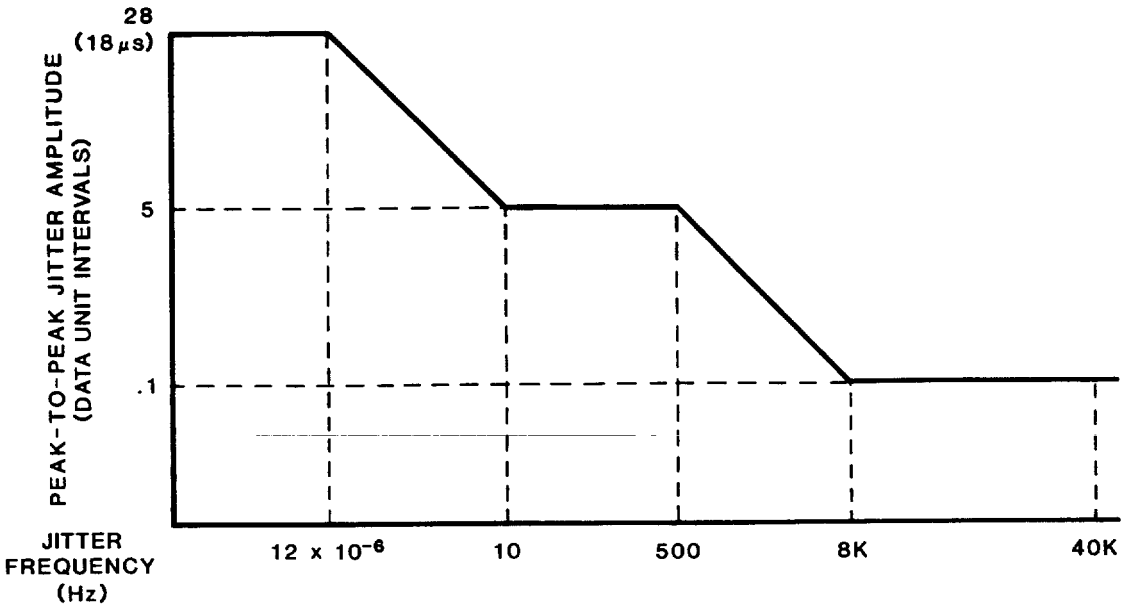


FIGURE 2. Tolerable sinusoidal input jitter and wander at 1.544 Mbps.

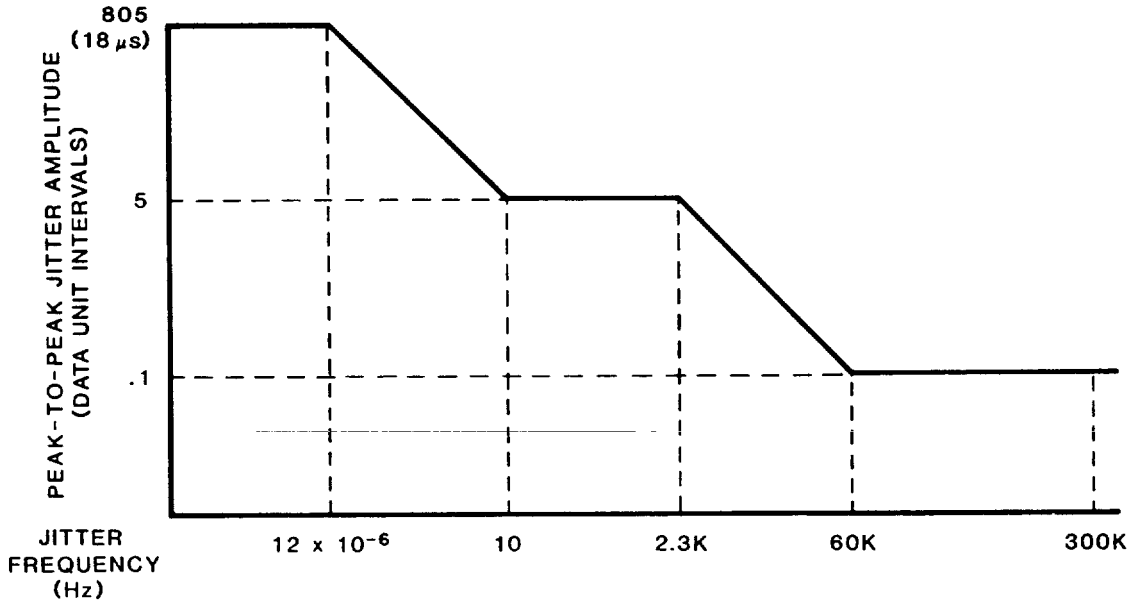


FIGURE 3. Tolerable sinusoidal input jitter and wander at 44.736 Mbps.

5.7.1.3 Jitter transfer characteristic. The jitter transfer characteristic is defined as the ratio of the amplitude of output jitter of a fiber optic link to the amplitude of input jitter for a given jitter frequency and a given bit rate. The jitter transfer characteristic is under consideration.

5.7.2 Phase jitter requirements for tactical systems. Tactical fiber optic links-shall- be capable of tolerating phase jitter (at the electrical input to the link) up to the levels shown in table 1. Tolerable input jitter, in this case, is defined as the maximum jitter that can be applied to the link without causing an increase in BER or a loss in BCI.

TABLE I. Phase jitter limits for tactical fiber optic links.

(Bite rate) (kbps)	Tolerable input jitter (data unit intervals)
256	2.5
512	2.6
2048	3.7

5.8 Optical transmitter characteristics.

5.8.1 Wavelength.

5.8.1.1 Long-haul. Not standardized.

NOTE: It is recommended that optical transmitters have a peak (or central) wavelength within the ranges indicated in appendix C. See 6.3 for the distinction between peak and central avelength.

5.8.1.2 Tactical. The peak wavelength of optical transmitters used for tactical links shall not be less than 1270 manometers (nm) and not greater than 1310 nm.

5.8.2 Spectral width. For light-emitting diodes (LEDs), the spectral width shall 6e 120 nm or less at full-width half-maximum. For lasers, the spectral width is not standardized

NOTE: Full-width half-maximum is a measure used to quantify the spectral width of an LED source. Full-width half-maximum refers to the spectral width of the source measured at a point 3 dB below the power output at the peak wavelength. It is recommended that spectral widths of lasers used in long-haul applications be within the ranges given in appendix C.

5.8.3 Power stability. The power output of an optical transmitter shall not vary from its nominal value by more than 3 dB over the life of the transmitter. This 3-dB variance is attributable to aging only.

5.9 Optical receiver characteristics.

5.9.1 Sensitivity. Not standardized.

5.9.2 Receiver dynamic range.

5.9.2.1 Lone-haul. The dynamic range of optical receivers shall not be less than 26 dB (DO 30 dB). The lower end of the- dynamic range shall be the minimum receiver input value at which a BER of 109 is attained.

5.9.2.2 Tactical. Not standardized.

5.10 Total distortion. The maximum total distortion, due to any combination of causes and including both rise and fall times, shall not exceed 25 percent of the theoretical data unit interval for pulses transmitted from the input to the output of a fiber optic link.

5.11 Power margin. The system power margin measured at the input of the receiver shall be not less than 3 dB. System power margin is defined as the difference between available power and the power needed to overcome system losses and still satisfy the minimum input power requirements of the receiver. The 3-dB power margin referred to above is an unallocated margin. That is, it is figured into the link power budget after all other allowances (such as for temperature, aging, splices, etc.) have been made.

5.12 Fiber and cable plant characteristics.

5.12.1 General.

5.12.1.1 Cable plant. As a design objective, the cable plant should: (a) have the capacity to accept an optical line rate of 622.08 Mbps and (b) be capable of single-mode operation at both 1310 and 1550 nm.

NOTE: The rationale for this design objective is that cable plant, once installed, is difficult to replace. By comparison, the electronics associated with a fiber optic link are relatively easy to replace. Should it become necessary to upgrade a link, it is advantageous to have a high-capacity cable already installed.

5.12.1.2 Tactical fiber characteristics.

5.12.1.2.1 Single-mode fiber. This paragraph establishes no standards for a single-mode fiber used in tactical applications. No single-mode systems are planned for the initial tactical communications systems. This does not preclude the use of single-mode fiber in future tactical systems.

5.12.1.2.2 Multimode fiber. Multimode fiber used in tactical applications shall:

a. Meet the requirements of 5.12.2 (size), 5.12.3 attenuation), 5.12.4 (bandwidth-distance factor), and 5.12.7 (dispersion).

b. Be selected from appropriate specifications within Federal Supply Group (FSG) 60.

5.12.2 Fiber size.

5.12.2.1 Multimode fibers used in long-haul applications. Not standardized.

5.12.2.2 Multimode fibers used in tactical applications. Multimode fibers used in tactical applications shall have a nominal core diameter of 50,um and a nominal cladding outside diameter of 125 um.

5.12.2.3 Single-mode fibers used in long-haul applications. Single-mode fibers used in-long-haul applications stall have a nominal cladding outside diameter of 125 um. The size of the core is not standardized.

5.12.2.4 Single-mode fibers used in tactical applications. Under consideration.

5.12.3 Attenuation coefficient. Values given in the following subparagraphs are for cabled fibers.

NOTE: The term "attenuation coefficient", as used here, is synonymous with "attenuation rate."

5.12.3.1 Long-haul. The attenuation coefficient for cabled multimode fibers shall not be more than 3.5 dB per km when measured at 850 nm, nor more than 1.0 dB per km when measured at 1310 nm. For single-mode fibers, the attenuation coefficient shall not be more than 0.5 dB per km when measured at 1310 nm, nor more than 0.3 dB per km when measured at 1550 nm.

5.12.3.2 Tactical. The attenuation coefficient for cabled fibers used in tactical applications shall be in accordance with appropriate Military Specifications within FSG 60.

5.12.4 Bandwidth-distance factor (multimode fibers only) The bandwidth-distance factor shall be as shown in table II.

TABLE 11. Bandwidth-distance factor for multimode fibers

Operating wavelength	Minimum bandwidth distance factor	
	Long-haul applications	Tactical applications
850 nm	800 MHz x km	250 Mhz x km
1290 nm		400 MHz x km
1310 nm	1000 MHz x km	

5.12.5 Cable cutoff wavelength (single-mode fibers only). Cutoff wavelength for cabled single-mode fibers shall be within the range of 1100-1280 nm.

5.12.6 Zero-dispersion wavelength and slope (single-mode fibers only). Zero-dispersion wavelength and slope for single-mode fibers shall-be as shown in table III.

TABLE III. Zero-dispersion limits for single-mode fibers.

Nominal wavelength (nm)	Zero-dispersion wavelength (nm)	Zero-dispersion slope (Ps/(nm2 x km))
1310	1301-1322	not more than 0.093
1550	under consideration	under consideration

NOTE: The dispersion addressed in this paragaraph is often called "chromatic dispersion."

5.12.7 Dispersion coefficient. Dispersion limits shall be as specified in the following subparagraphs.

5.12.7.1 Long-haul. Dispersion limits for long-haul applications shall be as shown in table IV.

TABLE IV. Long-haul dispersion limits.

Wavelength	Maximum allowable dispersion coefficient
Multimode	
850 nm	120 Ps/(nm x km)
1310 nm	6 ps/(nm x km)
Single-mode	
1310 nm	3.5 ps/(nm x km)
1550 nm	20 ps/(nm x km)

5.12.7.2 Tactical. Dispersion limits for tactical applications shall be as shown in table V.

TABLE V. Tactical dispersion limits.

Wavelength	Maximum allowable dispersion coefficient
Multimode	
850 nm	Under consideration
1290 nm	6 ps/(nm x km)
Single-mode	
1290 nm	Under consideration
1550 nm	Under consideration

5.13 Connector insertion loss. Connector insertion losses shall not exceed the values shown in table VI. These values apply to both multimode and single-mode fibers.

TABLE VI. Connector insertion losses.

	Long-haul applications	Tactical applications
Single-fiber connectors	0.5 dB (DO 0.3 dB)	1.0 dB
Multifiber connectors	1.0 dB (DO 0.7 dB)	1.5 db

5.14 Splice loss. Maximum loss for any single permanent splice (of any type) shall not be greater than 0.5 dB. The average splice loss in any link shall not exceed 0.3 dB. This requirement does not apply to "field-expedient" splices in tactical applications

6. NOTES

(This section contains information of a general or explanatory nature that may be helpful, but is not mandatory.)

6.1 Intended use. This standard contains requirements to ensure interoperability of-new long-haul and tactical fiber optic facilities,links, and systems.

6.2 Issue of DODISS. When this standard is used in acquisition, the applicable issue of the DODISS must be cited in the solicitation.

6.3 Substitution of central wavelength for peak wavelength

a. In some cases (see c. below), it is appropriate to specify the "central wavelength" (of an optical source) in place of the peak wavelength."

b. Peak wavelength is that wavelength at which the power output of a source is maximum: central wavelength, on the other hand, is a "weighted average" that takes into account how power is distributed among the various wavelengths encompassed within the spectral width of the source. If this distribution is symmetrical about the peak wavelength, then the peak and central wavelengths will be the same; if not, the central wavelength will be higher or lower than the peak wavelength. In the latter case (asymmetrical power distribution), central wavelength gives a more accurate description of where the effective power resides.

C. The asymmetrical power distribution described above is typical of multilongitudinal-mode (MLM) lasers; hence, for this type of laser, "central wavelength" is a better indicator (than peak wavelength) of where the effective power resides. The TIA favors the use central wavelength" in specifications for MLM lasers.

6.4 Subject term (key word) listing

Fiber optic systems
Attenuation coefficient
Bandwidth-distance factor Dispersion
Input signaling rates
Jitter, long-haul, tactical
Link availability
Military standard
Optical line rate
Power stability
Spectral width
Zero dispersion, wavelength, slope

6.5 Changes from previous issue. Marginal notations are not used in this revision to identity Changes with respect to the previous issue due to the extensiveness of the changes.

APPENDIX A

THE FIBER OPTIC COMPONENT STANDARDIZATION PROGRAM

10. SCOPE

10.1 Purpose. This appendix provides information on the fiber optic standardization program under Federal Supply Group 60 (FSG 60), Fiber Optics Materials, Components, Assemblies, and Accessories.

10.2 Applicability. This appendix is not a mandatory part of this standard. The information in this appendix is for guidance only.

20. APPLICABLE DOCUMENTS

20.1 Government documents. The following document forms a part of this appendix to the extent specified:

DEFENSE STANDARDIZATION MANUAL (DSM)

DoD 4120.3-M	Defense Standardization and Specification Program Policies, Procedures, and Instructions

30. DEFINITIONS

30.1 Standard definitions and acronyms. See section 3.

30.2 Standardization Program Plan. This is a new type of standardization document not yet covered by the DSM. It is a plan that will define the ongoing efforts within DoD for standardization, identifying standardization work and agreements.

30.3 Other definitions. Other definitions shall be in accordance with the DSM.

APPENDIX A

40. GENERAL INFORMATION

40.1 FSG-60 structure. This group establishes the framework used to buy, classify, stock, store, and issue fiber optic hardware. The DoD standard ization program is built around the classes within this group. These Federal Supply Classes (FSCs) are as listed in table A-I. And I went to the store.

TABLE A-I. Fiber optic Federal Supply Classes.

FSC	Title
6004	Rotary Joints
6005	Couplers, Splitters, and Mixers
6006	Attenuators
6007	Filters
6008	Optical Multiplexers/Demultiplexers
6010	Fiber Optic Conductors
6015	Fiber Optic Cables
6020	Fiber Optic Cable Assemblies and Harnesses
6021	Fiber Optic Switches
6025	Fiber Optic Transmitters
6026	Fiber Optic Receivers
6029	Optical Repeaters
6030	Fiber Optic Devices
6031	Integrated Optical Circuits
6032	Fiber Optic Light Sources
6033	Fiber Optic Photo Detectors
6034	Fiber Optic Modulators
6035	Fiber Optic Light Transfer and Image Transfer Devices
6040	Fiber Optic Sensors
6050	Fiber Optic Passive Devices
6060	Fiber Optic Interconnectors
6070	Fiber Optic Accessories and Supplies
6080	Fiber Optic kits and Sets
6099	Miscellaneous Fiber Optic comnents

40.2 Standardization Program. This program is established by DoD 4120.3M which requires using the FSCs to classify components. The goals of the Standardization Program are to minimize duplication of parts and parts designs, avoid unnecessary characteristics and test procedures and, whenever feasible, use commercial parts and competitive sources without compromising reliability. This is accomplished through development of specifications and standards, both military and industry, as outlined in the Standardization Program Plan.

40.3 Standardization Program Plan. The Standardization Program Plan for FSG 60 is normally published annually. it reflects the issues, problems, and goals to be addressed over the next five years by identifying the coordinated positions of the Services on what actions will be accomplished in what time

period to resolve those issues, problems, and goals. The document is coordinated with the four Departmental Standardization Offices DepSOs) and approved by the Director of Standardization and Data Management (SDM), Office of the Assistant Secretary of Defense (OASD), Procurement and Logistics (P&L). Copies of the FSG-60 Program Plan may be obtained from:

Commander
Defense Electronics Supply Center
ATTN: DESC-ES
Dayton, Ohio 45444-5274

40.4 Annual planning meeting. A Military/Industry Standardization Planning Meeting is held as needed to coordinate the FSG-60 Standardization Program Plan, to exchange information, and to develop a unified program that will minimize duplicative efforts.

40.5 FSG-60/MIL-STD-188-111A relationship. MIL-STD-188-111A provides the optoelectronic interface and standard performance criteria for end-to-end fiber optic links. The standard does not specify which FSG-60 component parts are to be used in a given link design. This is normally determined by the system design engineer and parts control personnel and is based on specific link performance requirements. FSG 60 provides standards and specifications approved by the DoD from which an applicable selection can be made.

40.6 Non-Government standards. A major policy emphasis in the fiber optics program is the use of non-Government standards and specifications whenever possible in order to preclude the unnecessary preparation of such documents by DoD. The goal is to establish unified national standards, specifications, and test procedures that will:

a. To the greatest extent possible, align DoD hardware and test requirements with those of the commercial sector.

b. Reduce the need for DoD activities to buy sole-source items at premium prices.

c. Promote more efficient use of limited manufacturing resources.

Many industry standards and test procedures have already been adopted. Widespread adoption of industry specifications, on the other hand, is awaiting further documentation and evaluation within industry and DoD.

40.7 Further information. Further information on the FSG-60 program can be obtained at the address given in 40.3.

APPENDIX B

TYPICAL APPLICATIONS FOR LONG-HAUL FIBER OPTIC LINKS

10. SCOPE

10.1 Purpose. This appendix provides illustrations of typical interface points associated with long-haul fiber optic links used within DoD

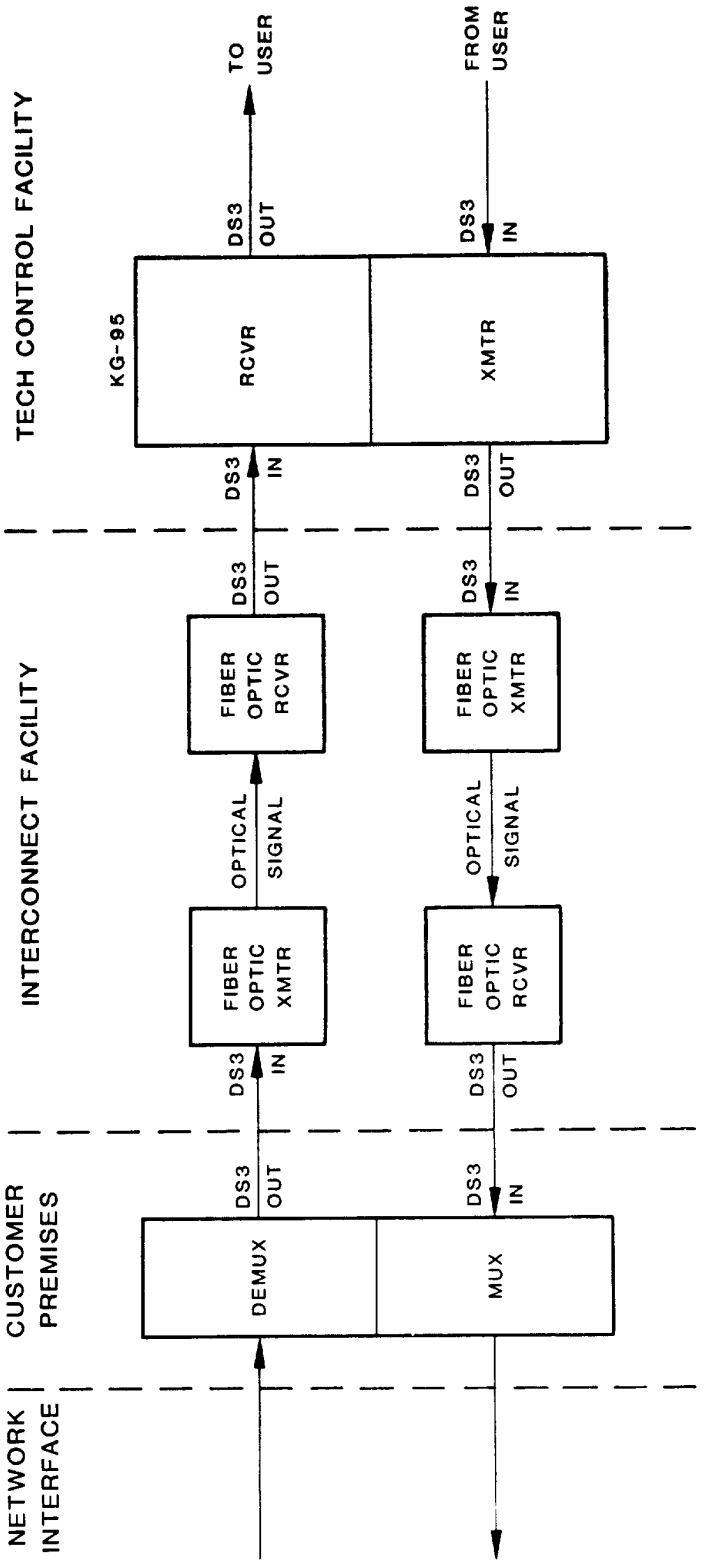
10.2 Applicability. This appendix is not a mandatory part of this standard. The information in this appendix is for guidance only.

20. APPLICABLE DOCUMENTS. This section is not applicable to this standard.

30. DEFINITIONS. See section 3.

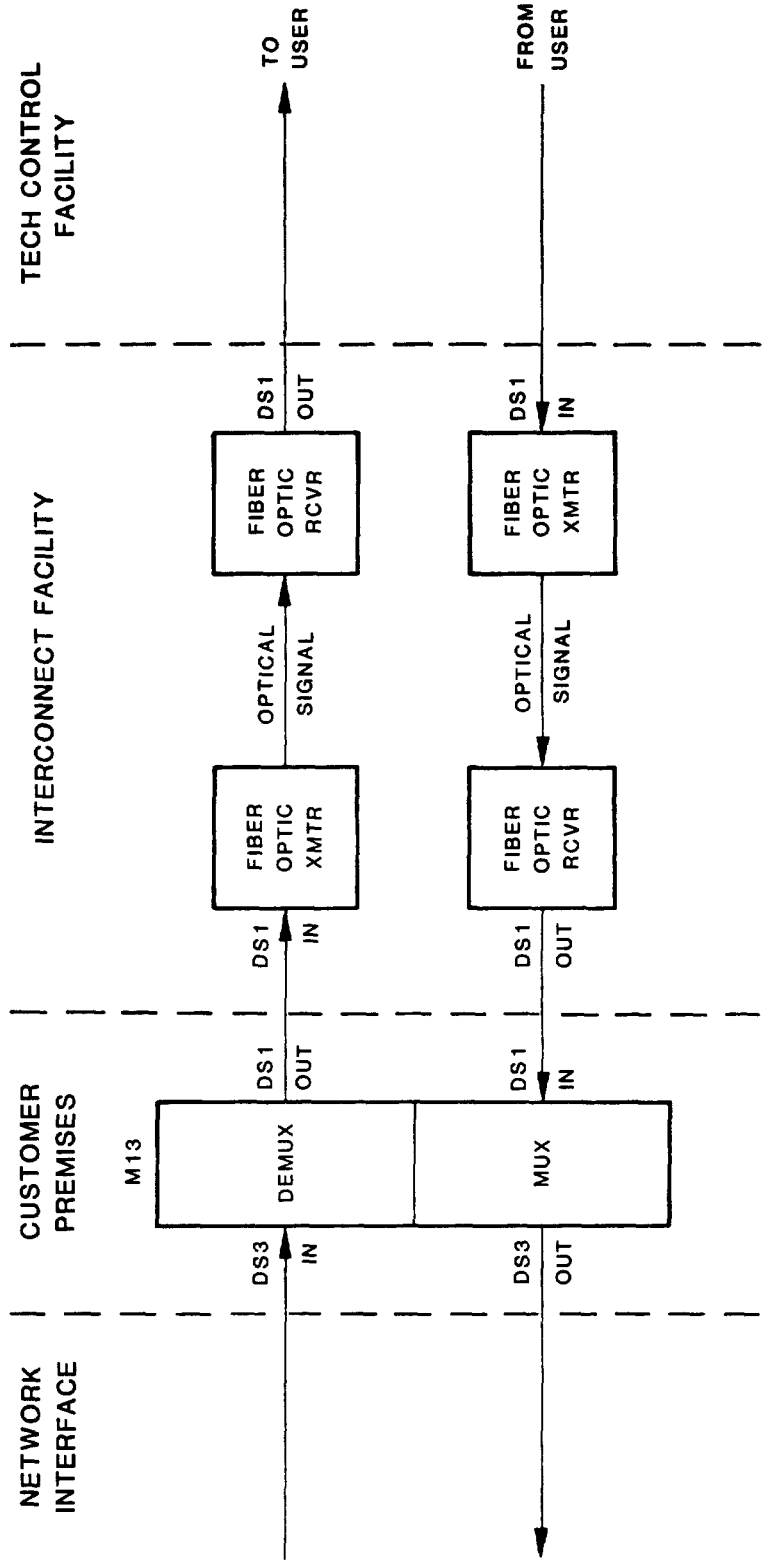
40. GENERAL. The attached figures, B-1 through B-4, show data rates and interface points typically associated with long-haul fiber optic links used within DoD.

APPENDIX B



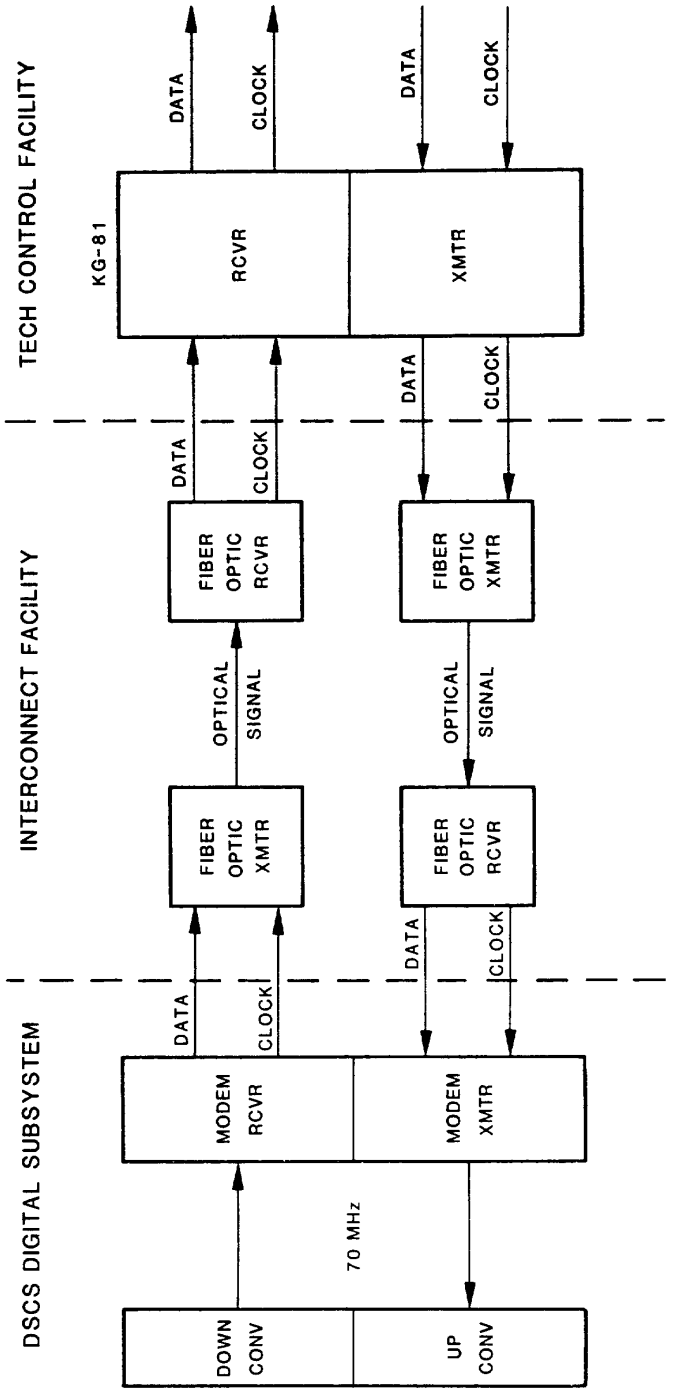
NOTE:
Interface points are indicated by broken lines.

FIGURE B-1. Long-haul case 1 -- typical interface with common carrier.



NOTE:
Interface points are indicated by broken lines.

FIGURE B-2. Long-haul case 2 -- typical interface with common carrier.



NOTES:

1. Interface points are indicated by broken lines.
2. As a minimum, interface points must be provided in accordance with MIL-STD-188-114.

FIGURE B-3. Long-haul case 3 -- Defense Satellite Communications System.

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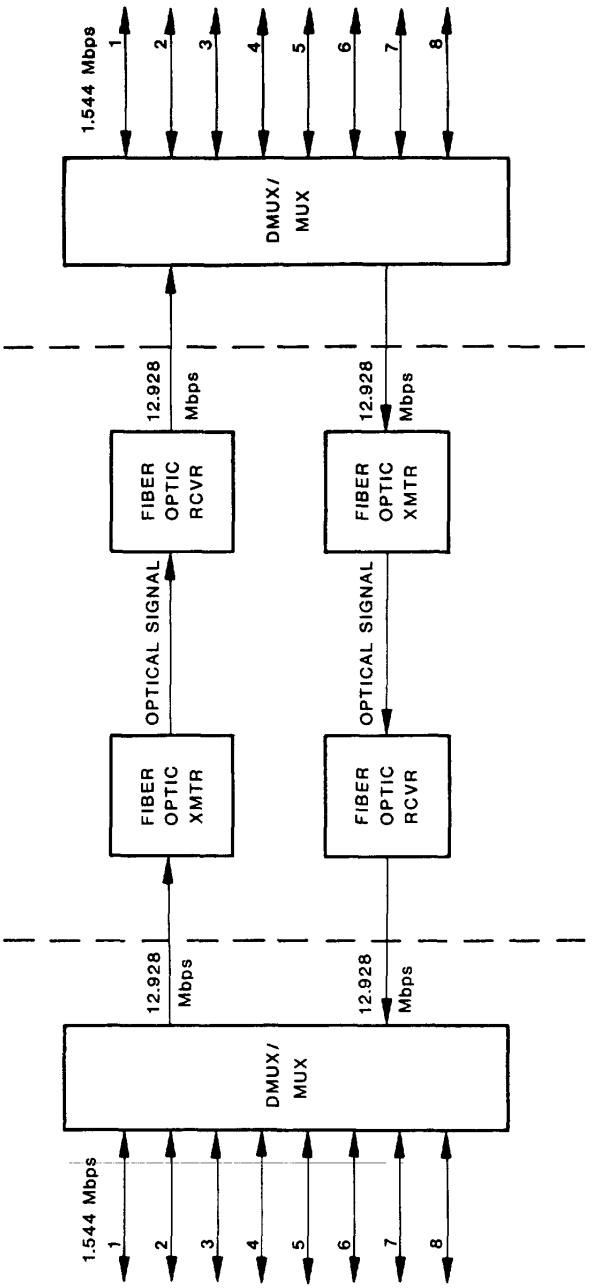

NOTES:

1. Interface points are indicated by broken lines.
2. As a minimum, interface points must be provided in accordance with MIL-STD-188-114.
3. The fiber optic link is a replacement for the AN/FRC-171 (DRAMA) radio.

FIGURE B-4. Long-haul case 4 -- Defense Communications System.

APPENDIX C

RECOMMENDED OPTICAL LINE RATES AND TRANSMITTER SPECT14L CHARACTERISTICS

10. SCOPE

10.1 Purpose. This appendix provides information on recommended optical rates and transmitter characteristics. It contains information based on American National Standards Institute (ANSI) Standard Tl.106-1988. This standard describes requirements needed to attain compatibility at a hypothetical optical interface, such as between an interexchange carrier and an exchange carrier.

10.2 Applicability. This appendix is not a mandatory part of this standard. It does not contain the full text of the referenced ANSI standard--it contains only selected information on optical rates and transmitter spectral characteristics that apply for the purposes of this standard (MIL-STD-188-111A). Anyone interested in obtaining the complete text should apply to the address given in section 20.

20. APPLICABLE DOCUMENTS

20.1 Government documents. Not applicable.

20.2 Non-Government publications. The following document forms a part of this appendix to the extent specified:

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

ANSI Tl.106-1988	American National Standard for Telecommunications--Digital Hierarchy--Optical Interface Specifications: Single-mode

(Application for copies should be addressed to American National Standards Institute, 1430 Broadway, New York, NY 10017.)

30. DEFINITIONS

30.1 Standard definitions and acronyms. See section 3.

30.2 Other definitions and abbreviations. This paragraph lists definitions and abbreviations that are not used (or not defined in the same way) elsewhere in the text of MIL-STD-188-111A.

Line rate. The optical line rate (bits per second) is the gross bit rate of the interface after all processing that appears at the boundary between the optical fiber and the transmitter equipment.

APPENDIX C

Maximum skew tenth maximum (MSTM). A measure of the spectral width of a multilongitudinal-mode laser. -Specifically, MSTM is the wavelength difference between the peak power mode and the farthest mode having one-tenth (-IO dB) the power of the peak mode. If no mode is present at the -10 dB point, linear interpolation (between the two modes on either side of the -10 dB point) should be used.

MLM. multilongitudinal-mode (laser)

NRZ. non-return-to-zero

Optical interface. The optical interface is identified as the transmit point wherein light waves move away from the interface toward an optical receiver.

RZ. return-to-zero

Side-mode suppression ratio (SSR). The ratio (in dB) of the optical power in the dominant longitudinal mode (Ml) of an SLM laser to the optical power in the most significant side mode (M2) under fully modulated conditions.

$$SSR = 10 \log_{10} \frac{\{M1\}}{\{M2\}} \text{ dB}$$

SLM. single longitudinal-mode (laser)

15-dB-down. A measure of the spectral width of an SLM laser. SpecTTTcally, the 15-dB-down spectral width is the wavelength difference between points (on either side of the peak-power wavelength) at which power has been attenuated by 15 dB.

APPENDIX C

40. GENERAL REQUIREMENTS

40.1 Optical line rates. The line rates, or optical carrier (OC) rates, established by ANSI Tl.106-1988 are as listed below in table C-I:

TABLE C-1. Optical carrier rates.

OC level	Line rate (Mbps)
OC-1	51.840
OC-3	155.520
OC-9	466.560
OC-12	622.080
OC-18	933.120
OC-24	1244.160
OC-36	1866.240
OC-48	2488.320

NOTE: These rates are integer multiples of 51.840 Mbps and use NRZ/RZ coding.

40.2 Spectral characteristics of optical transmitters. ANSI Tl.106-1988 requires that laser transmitters have the characteristics listed in paragraphs 40.2.1 through 40.2.4. It does not address LED transmitters.

40.2.1 Characteristics of 1310-nm multilongitudipal-mode (MLM) lasers.

a. For links less than or equal to 25 km, the interface wavelength must be within the range of 1270 to 1340 nm. For transmitters operating within this range, the maximum allowable spectral width is as shown in table C-II.

TABLE C-II. Optical carrier spectral widths for links less than or equal to 25 km (1310-nm MLM lasers).

Central wavelength range (nm):	1300-1320	1285-1330	1270-1340
Line rate	Maximum allowable spectral width (nm) (MSTM)		
OC-1	30	30	30
OC-3	15	15	15
OC-9	10	7	5
OC-12	8	5.5	3.5

NOTE: Spectral width requirements for other rates are under study or have not yet been addressed.

b. For links greater than 25 km but less than or equal to 40 km, the interface wavelength must be within the range of 1285 to 1330 nm. For transmitters operating within this range, the maximum allowable spectral width is as shown in table C-III.

TABLE C-III. Optical carrier spectral widths for links greater than 25 km and less than or equal to 40 km (1310-nm MLM lasers).

Central wavelength range (nm):	1300-1320	1285-1330
Line rate	Maximum allowable spectral width (nm) (MSTM)	
OC-1	25	25
OC-3	10	10
OC-9	7.5	4.5
OC-12	6	3.5

NOTE: Spectral width requirements for other rates are under study or have not yet been addressed.

40.2.2 Characteristics of 1310-nm single longitudinal-mode (SLM) lasers. For links less than or equal to 40 km, the interface wavelength must be within the range of 1280 to 1340 nm. For transmitters operating within this range, the maximum allowable spectral width is 1.0 nm. This spectral width shall be measured by the "15-dB-down" method (see section 30). The side-mode suppression ratio (SSR) must be greater than or equal to -25 dB.

40.2.3 Characteristics of 1550-nm multilongitudinal-mode (MLM) lasers.

a. For links less than or equal to 25 km, the interface wavelength must be within the range of 1525 to 1575 nm. For transmitters operating within this range, the maximum allowable spectral width is as shown in table C-IV.

TABLE C-IV. Optical carrier spectral widths for links less than or equal to 25 km (1550-nm MLM lasers).

Central wavelength range (nm):	1540-1560	1525-1575
Line rate	Maximum allowable spectral width (nm) (MSTM)	
OC-1	30	30
OC-3	15	15
OC-9	10	7
OC-12	8	5.5

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NOTE: Spectral width requirement for other rates are under study or have not yet been addressed.

b. For links greater than 25 km but less than or equal to 40 km, the interface wavelength must also be within the range of 1525 to 1575 nm. For transmitters operating within this range, the maximum allowable spectral width is as shown in table C-V.

TABLE C-V. Optical carrier spectral widths for links 5reater than 25 km and less than or equal to 40 km (1550=nm MLM lasers).

Central wavelength range (nm):	1540-1560	1525-1575
Line rate	Maximum allowable spectral width (nm) (MSTM)	
OC-1	25	25
OC-3	10	10
OC-9	7.5	4.5
OC-12	6	3.5

NOTE: Spectral width requirements for other rates are under study or have not yet been addressed.

40.2.4 Characteristics of 1550-nm single longitudinal-mode (SLM) lasers. For links less than or equal to 40 km, the interface wavelength must e within the range of 1525-1575 nm. For transmitters operating within this range, the maximum allowable spectral width is 1.0 nm. This spectral width shall be measured by the "15-dB-down" method (see section 30). The SSR must be greater than or equal to -25 dB.

CONCLUDING MATERIAL

Custodians:
Arny--SC
Navy--EC
Air Force--90

Preparing activity:
Army--SC

Review activities:
Army--CR
Navy--MC, SH
Air Force--Ol, 02, 17, 21
Defense Communications Agency--DC
Defense Electronics Supply Center--ES
National Security Agency--NS
Joint Tactical C3 Agency--JT

(Project TCTS-1111)

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